**RJM Corporation**
Ten Roberts Lane
Ridgefield, CT 06877
203 438-6198

June 17, 1991

RJM

RECEIVED
JUL 02 1991
I.P.P.

Mr. Aaron Nissen
Results Supervisor
Intermountain Power Service Corporation
Route 1, Box 864
Delta, UT 84624

Re: Intermountain Power Generating Station
RJM Project No. 915332
RJM Proposal No. 910614

Dear Aaron:

Enclosed is one copy of RJM Corporation's On-Site Diagnostic and Corrective Action Report and budgets. A copy has been sent to Raffi Krikorian at LADWP. Also enclosed are the burner drawings which you have requested to be returned to you. The reference book I recommend to you is Combustion Aerodynamics by J.M Beér and N.A. Chigier, 1983. Published by Robert E. Krieger Publishing Company, Malabar, Florida.

RJM Corporation is prepared to proceed on part or all of the proposed program upon your written authorization to proceed.

Very truly yours,

Richard J. Monro
President

RJM/ca
Ipgssite.ltr

cc: Raffi Krikorian, LADWP

Enclosures

| | |
|---|---|
| J. P. MUSTO | ✓ |
| C. E. FINNEGAN | ✓ |
| D. E. LEOPARDI | |
| K. E. SOUTH | |
| D. C. MURDOCK | |
| S. M. MATHIS | |
| D. A. PATTEE | |
| S. N. LOVELL | |
| M. ROYLANCE | |
| P. O.LOR | |
| C. WHITING | |
| D. WALKER | |
| | |
| A & B FILE | D |

IGS 91-3

ON-SITE DIAGNOSTIC

AND

CORRECTIVE ACTION PROGRAM

for

Intermountain Power Service Corporation
Route 1, Box 864
Delta, UT 84624

Attention: Mr. Aaron Nissen
Results Supervisor

June 17, 1991
Project No. 915332
Proposal No. 910614
Ipgssite.rep

*By*
**RJM Corporation**
Ten Roberts Lane
Ridgefield, CT 06877
203 438-6198

Reliability and performance solutions

RJM

Prepared by:

Richard J. Monro

IP7_000160

TABLE OF CONTENTS

## 1.0 INTRODUCTION

Intermountain Power Generating Station (IPGS) has two 820 MW coal fired B&W units. There are 48 B&W Mark 5, dual register, low $NO_X$ burners in each unit in an opposed firing configuration. The burners are less than five years old and have experienced severe thermal destruction.

RJM Corporation has been requested by Intermountain Power Service Corporation (IPSC) to visit the facility for on-site diagnostic purposes and to develop a corrective action program which would minimize or eliminate the problems experienced to date. This report details the findings of RJM Corporation's site visit to the plant on June 5 and 6, 1991 and presents a comprehensive action plan to address the issues raised during that visit.

## 2.0 PROGRAM OBJECTIVES

During the site visit, plant personnel and RJM Corporation derived the following objectives to be addressed by this program:

1. Eliminate burner thermal destruction
2. Stop burner line fires
3. Minimize furnace eyebrow formation
4. Balance burner air and fuel flows

## 3.0 CONCLUSIONS

Based upon in-depth discussions with plant personnel, a review of operating performance and historical data and an inspection of the units, the following conclusions are in order:

1. The expected service life for dual zone low $NO_X$ burners of the Mark 5 type is the service life of the unit - i.e., 25 to 30 years.

2. The burners at IPGS are severely damaged and have prematurely reached the end of their full service life.

3. The thermal destruction of the burners is principally caused by two factors:

   a. Excessive Burner Swirl - Register air doors are closed to the 25% open position and the register air vanes are closed to the 30% open position which is causing an excessively high swirl on the burner. Recirculation effects resulting from this excessive swirl are causing hot furnace gases, approaching 3000° in temperature, to be drawn up-stream into the burner. This has resulted in severe thermal overheating and destruction of metal burner components.

   b. Poor Engineering Design - Critical burner structures exposed to high heat radiant heat flux have not been properly shielded. Inadequate allowances for thermal expansion due to temperature differences of as much as 700°F have resulted in warping of burner components and fracture of welded seams.

4. Burner line fires appear to be caused by coal residue left in coal pipes due to furnace [pulverizer] trips. The residue ignites due to hot furnace gases being brought into the burner as a result of excessive swirl.

5. Eyebrow formation is due to a recirculation pattern from the flame envelope onto the front wall. The recirculation is caused by excessive swirl on the burner. Coal ash having ash softening temperatures below 2300°F is contributing to the problem. Two of the six mine sources used at IPGS have ash fusion softening temperatures as low as 2100°F. Particles of such ash are very sticky at furnace temperatures and adhere to tube surfaces when recirculated to the furnace wall.

6. Airflow and possibly fuel flow imbalances exist in the unit and are indicated by $O_2$ differences in back-end profiles by as much as 1.5% $O_2$.

## 4.0 RECOMMENDATIONS

The corrective measures recommended by RJM Corporation are summarized below. Please see the Corrective Action Program of this report for a more in-depth discussion.

1. Replace the present burners with an improved design which has been optimized aerodynamically and mechanically.

2. IPSC and its consultants should have significant engineering input into the new burner design to insure that mechanical and dynamic design problems have been properly addressed and incorporated into the new design.

3. The burner design should be modeled using an axisymetric two dimensional airflow model to correctly set the proper swirl characteristics

of the burner. At a minimum, the following four dynamic characteristics must be mechanically designed into the burner:

a. Total burner swirl number = 0.3
b. Outer zone swirl number <0.3
c. Inner zone swirl number = 0.8 for flame stability
d. Ignition zone located approximately one-half the burner throat diameter downstream from the furnace wall.

4. A vane cascade type flame stabilizer (RJM's MZ flame stabilizer) should be installed for flame stability purposes.

5. Optimize the burner mechanical design using a computer model and finite element analysis to eliminate and/or accommodate thermal deformation stresses.

6. Use of coals having an ash fusion softening temperature less than 2300°F should be avoided or minimized to help prevent eyebrows from forming.

7. Air and fuel flows to the burners should be balanced to within ±3% using RJM's proprietary insitu airflow analysis technologies. Alternately a fluid dynamic or physical model might be used to balance air and fuel. RJM Corporation's insitu air distribution and fuel distribution balancing program is the most accurate of the three approaches since all measurement and data is derived from the physical unit being tested. Insitu balancing is recommended wherever possible.

## 5.0 CORRECTIVE ACTION PROGRAM

The following sections define problem origins and corrective actions to meet the objectives set forth in Section 2.0 of this report. In some cases, causative factors are interrelated. Therefore, the discussion may treat two or more problems simultaneously.

### 5.1 Combustion Aerodynamic and Mechanical Design Optimization

#### 5.1.1 Problem

The problems to be addressed by this section are:

1. Burner thermal destruction
2. Burner line fires
3. Eyebrow formation

#### 5.1.2 Dynamics

The above problems have a common causative factor exacerbated by one or more additional factors. The most serious common factor to all three problems is that the burner is improperly set-up with regard to combustion aerodynamics.

The secondary air doors are set at a 25% open position and the inner zone air vanes are set at a 30% open position. Such high closure positions on the register air doors force the burners to have an excessively high swirl number - i.e., a swirl number is excess of 0.6. Burners with swirl numbers in excess of 0.6 create a cyclonic vortex which, in the case of a two zone register design such as the B&W Mark 5, causes hot furnace gases in excess of 2500° and approaching 3000°F to enter into the burner. Figure 1 shows the effects of over-swirling the combustion air in a two zone register and resulting recirculation zones into the burner under both in-service and out-of-service conditions. When the burner is

# Overswirl Burner Flow Patterns

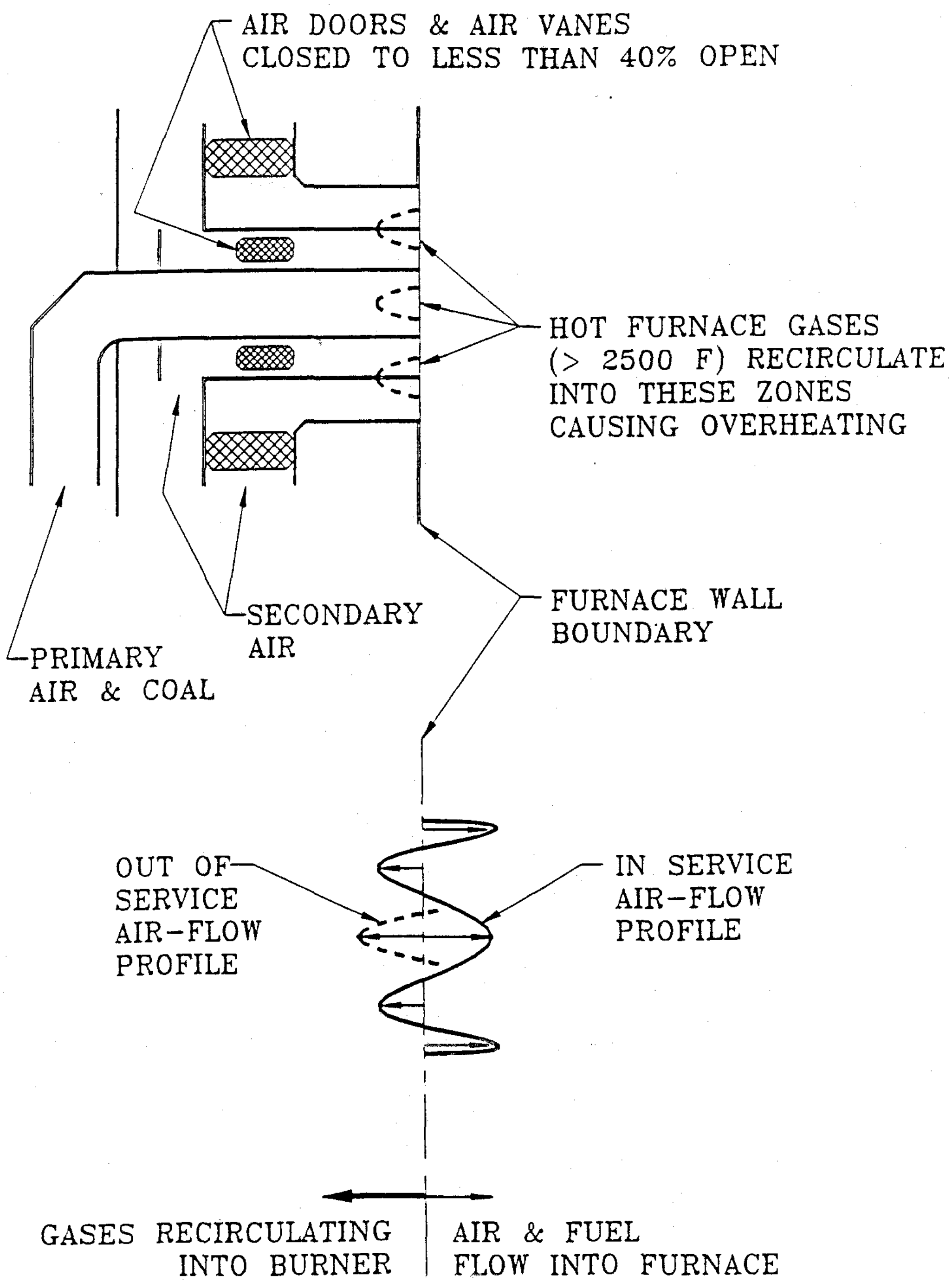



**Figure 1**

out of service, hot furnace gases also recirculate into the primary coal tube. Severe thermal overheating occurs in the burner with destructive changes to metal crystal structure, distortion of metal components, and ignition of any fuel laying in the bottom of the PC coal pipe.

### 5.1.3 Corrective Action

#### 5.1.3.1 Part 1 - Burner Airflow Model

An axisymetric two-dimensional airflow model should be made of the burner to establish correct swirl numbers and flame stabilization characteristics for the burner. The flow model should incorporate a coal flame stabilizer (RJM's MZ flame stabilizer) for flame stability and fuel/air mixing. The MZ coal stabilizer allows flame stability to be achieved with a swirl number of 0.8 while preventing recirculation of the hot furnace gases into the burner. The final model design should have a total burner swirl number of 0.3, an inner zone swirl number created by the MZ flame stabilizer equal to 0.8, and an outer zone swirl number of less than 0.3. A picture of the MZ flame stabilizer is shown in Figure 2 and the resulting flow patterns are depicted in Figure 3. Please note that the MZ flame stabilizer utilizes a twisted blade vane cascade very similar to gas turbine design. This twisted blade design is critical to prevent recirculation of hot furnace gases into the burner. A standard flat blade design such as employed by the air vanes in your two zone register creates a sharp V-shaped adverse pressure gradient line which invariably forces hot furnace gases up into the burner.

For this part of the program, your company will supply RJM Corporation with drawings of the burner and furnace geometry and relevant operating

# MZ Coal Flame Stabilizer

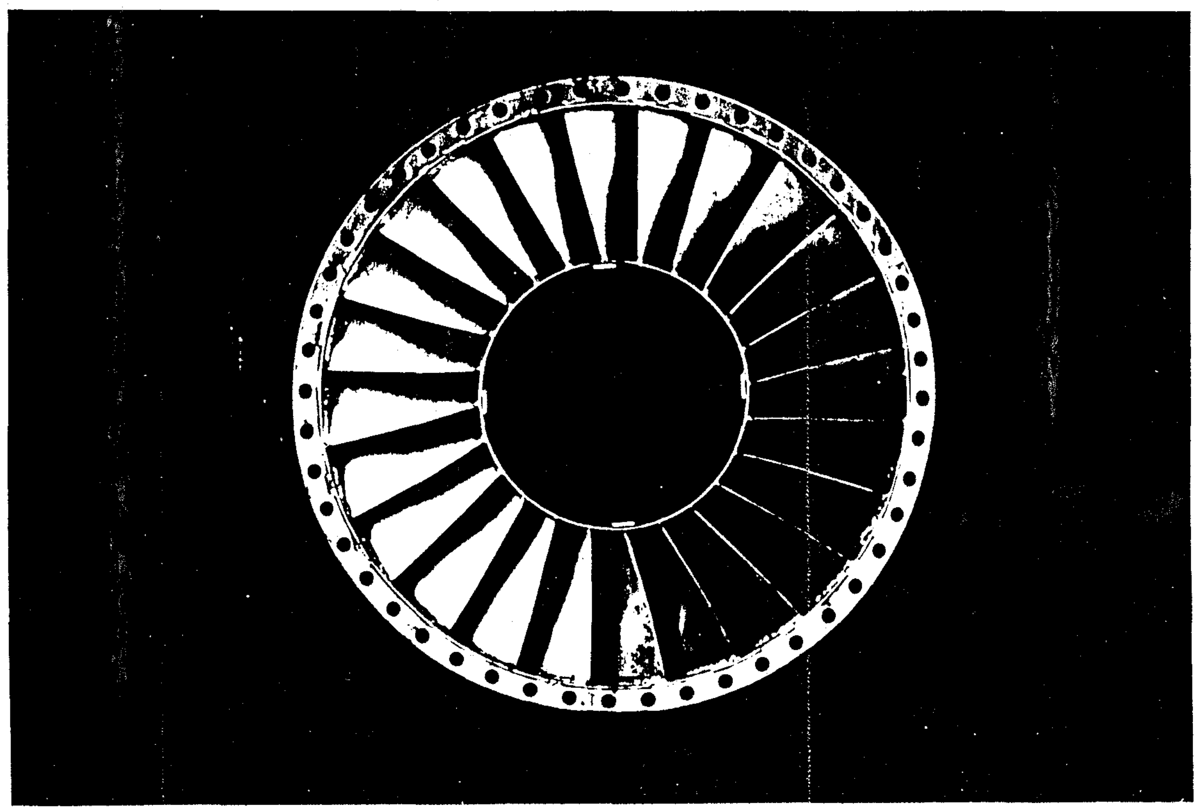


Figure 2

# Correct Burner Flow Pattern

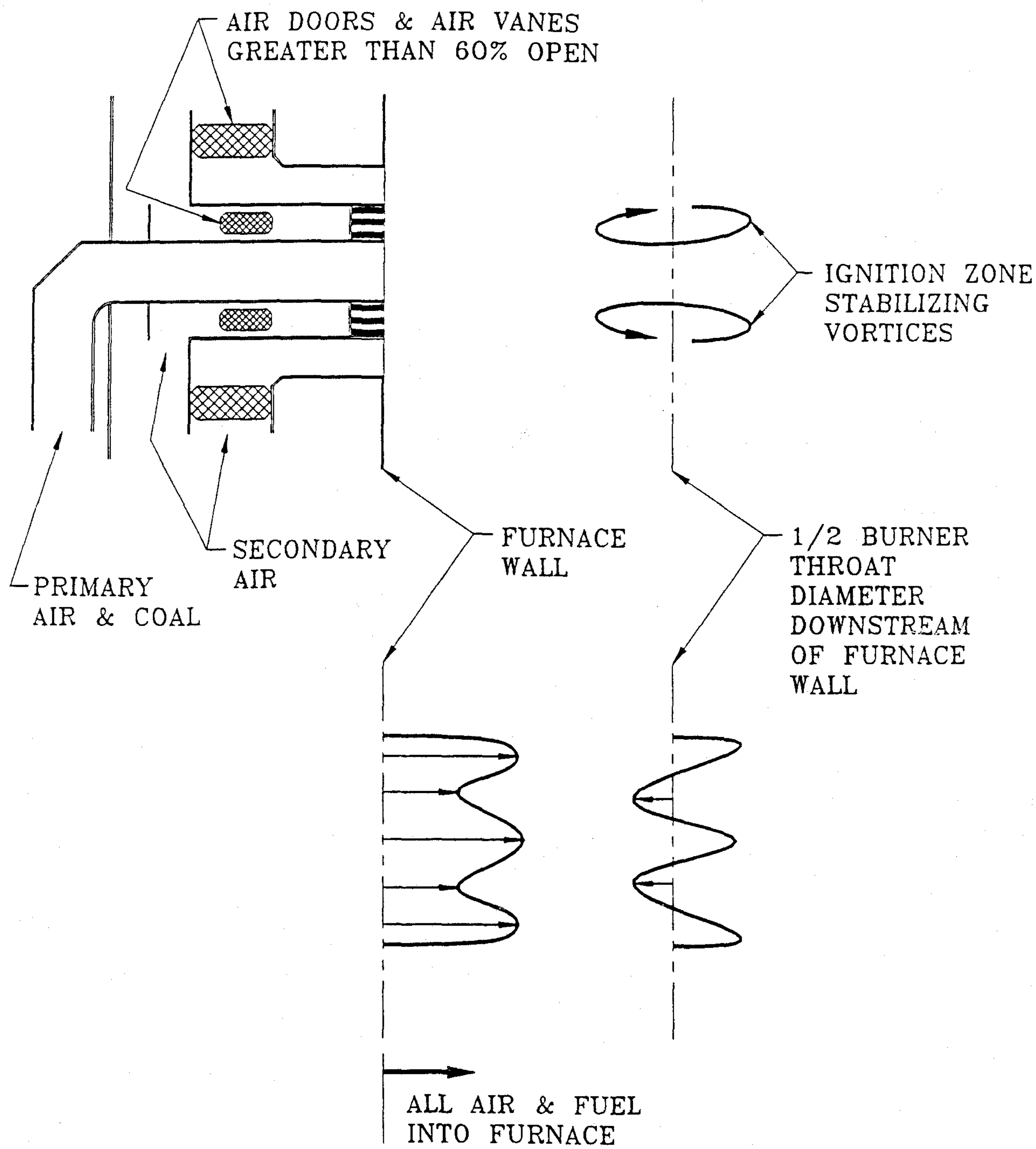



Figure 3

data, such as windbox-to-furnace differentials, combustion air temperatures, etc. The following steps will then be employed to establish the optimum aerodynamics for your burner design and operating conditions:

1. A two-dimensional axisymetric fluid model dynamics program will be used to analyze the aerodynamics of the burner airflow from the windbox to the burner exit. The aerodynamic solution uses the windbox pressure, temperature, furnace pressure drop, and burner geometric dimensions to calculate airflow, axial and tangential velocity, pressure profiles, and the proper swirl factor for the burner.

2. Numerous air door settings and flame stabilizer characteristics will be analytically investigated to establish the correct recirculation parameter. Recirculation parameter is defined as the difference between axial air momentum and the adverse static pressure gradient going into the furnace. Maintaining a slightly positive re-circulation parameter will insure a stable recirculation zone (necessary for good fuel/air mixing, a stable ignition zone, good carbon burnout and low excess air operation).

The MZ flame stabilizer is a vane cascade device optimized for performance on your burners. Installing an MZ flame stabilizer produces the following benefits:

1. Stable Flame Front - The MZ flame stabilizer creates a cyclonic vortex which aerodynamically stabilizes the flame front in a fixed position. The flame front location is one-half burner throat diameter downstream of the burner throat. The flame front is stable over the turndown range of the burner.

2. Windbox-to-Furnace Differential Pressures - The MZ flame stabilizer can be designed to optimize burner windbox-to-furnace differential pressures. Excessively low windbox-to-furnace differential pressures can be raised to optimized combustion efficiencies within existing forced draft fan characteristics and limitations.

3. Flame Shape - Aerodynamic characteristics of the MZ flame stabilizer are designed to maximize flame shape for your particular furnace type.

4. Swirl Control - Secondary air swirl is an important factor in pulverized coal combustion. The MZ flame stabilizer is designed for the optimum swirl number for your burner. More importantly the MZ flame stabilizer controls the swirl at the burner throat. Secondary air doors are maintained in the full open position.

5. Easy Installation - The MZ flame stabilizer is a vane cascade device fabricated with high temperature resistent materials. The stabilizer slides onto the pulverized coal burner tube. For two zone burners the stabilizer is welded to the inner zone OD wall. Installation or removal is accomplished within minutes without any modification to the existing burner.

6. Combustion Efficiency - The MZ flame stabilizer device controls burner swirl number and increases recirculation rates in the flame front so that both fly-ash carbon levels and excess air rates are reduced.

7. Based on the optimized aerodynamic model final air door settings, air vane settings are established. MZ flame stabilizer vane cascade design, shape and blade exit angles are also defined.

At the completion of the airflow modeling, RJM Corporation will manufacture 48 MZ flame stabilizers for installation by your company on the unit selected by IPSC.

### 5.1.3.2 Part 2 - Mechanical Design Optimization

Coal combustion results in high emissivity flames and high radiant heat fluxes to burner components. It is critical in proper burner design to analyze mechanical stresses which develop in a particular burner design due to thermal loading. The present design of the Mark 5 B&W two zone burner does not allow for proper thermal expansion of the secondary air zone back plate which results in warping of the back plate and fracture of the welds where the back plate attaches to the outer wall of the inner air zone. High radiant heat fluxes also result in severe thermal distortion of the secondary zone outer diameter cylinder where it seals to the boiler front wall.

In view of these factors, RJM Corporation strongly recommends that the mechanical design of the new burner be carefully analyzed to assure that it can accommodate the mechanical and thermal stresses imposed by the environment in which it operates. The following activities will be included as part of this program:

1. A detailed CAD model will be developed.

2. The CAD model will then be subjected to finite element analysis within the operating temperature regimes recorded by IPSC for the burner.

3. Based on the resulting stress analysis, the model will be redesigned to eliminate or minimize the stresses due to thermal loading.

4. The CAD model will also be refined to minimize heat influx loadings using insulation and shadowing of critical surfaces from radiant heat flux.

5. Final corrected design measures will be presented to IPSC for approval and incorporation into the B&W design.

### 5.1.3.3 Part 3 - Burner Line Fires

It appears that burner line fires are caused by the unique combination of over-swirl causing very high-temperature hot gases to enter the PC tube and the presence of a layer of fuel in the PC tube which results from an abnormal trip of pulverizers ~~the burner~~. Correction of the burner aerodynamics will prevent hot furnace gases from acting as an ignition source to the coal laying in the bottom of the PC tube. However, radiant heat flux when the burner is out-of-service may still provide sufficient energy to the coal layer to ignite a fire. Therefore, it is recommended as a safety precaution that, as soon as possible after the furnace trip, the primary air fans be restored to those burners so that the burners may be swept clean of any pulverized coal that may be present.

#### 5.1.3.4 Part 4 - Eyebrow Formation

Over-swirling the burners results in a wider, shorter flame which creates a recirculation eddy at the apex of the junction of the flame envelope with the furnace wall in the region of the burner throat. See Figure 4. This recirculation eddy recirculates fly ash to the burner wall. When the furnace fly ash has a sufficiently low ash softening temperature, it enters a plastic, sticky state which allows it to adhere to the furnace wall. Eyebrow formation results. Correcting the aerodynamics of the burner will substantially reduce eyebrow formation. However, it was noted in reviewing the coal analysis and specifications for the unit that the furnace was designed for burner coal ash having ash fusion softening temperatures greater than 2300°F. Two of the six mines supplying coal to the plant have ash fusion temperatures less than 2300°F and approaching 2100°F. It is recommended that, if possible, these two coal sources be eliminated, or at the very least, use of these coals be minimized for normal operations.

## 5.2 Air and Fuel Flow Balancing

### 5.2.1 Problem

Backend flue gas test results clearly indicates that there is an air and/or fuel flow imbalance to the unit. This is indicated by the fact that there is a 1.5% $O_2$ difference between the high excess air and low excess air readings from the sampling grid. Based on experience with the other units and anomalies in the design and set-up of the combustion air side of the unit, it is the opinion of RJM Corporation that most of the $O_2$ differences are associated with the combustion air rather than with the fuel. This conclusion is based upon the following factors:

# Burner Swirl vs. Eyebrow Formation

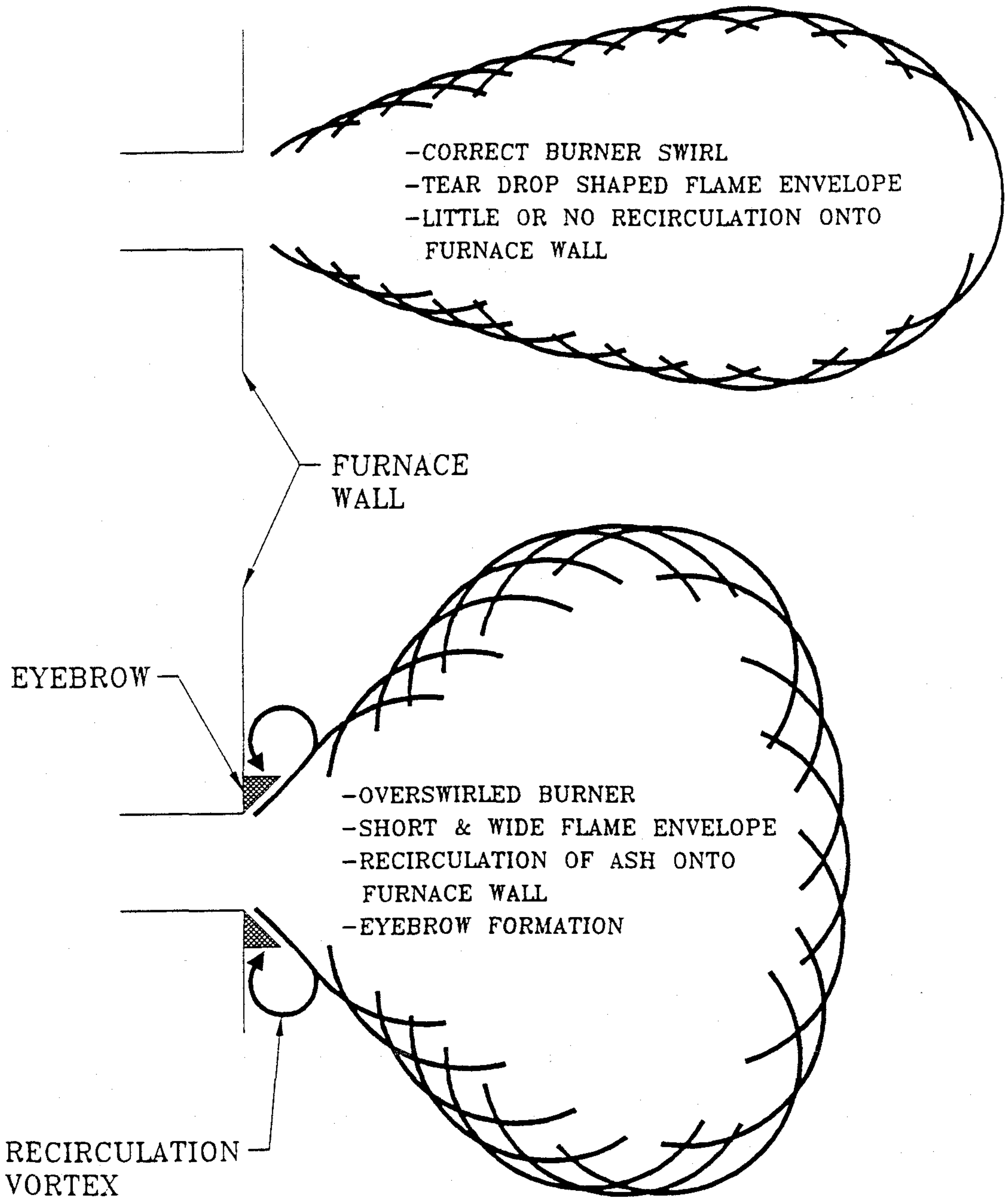



Figure 4

1. The combustion air ductwork makes abrupt 90° transitions into the individual windboxes. IPSC pito tube data in the region of the windbox inlet dampers clearly shows a velocity gradient across the duct which is typical of the airflow distortions created by such sharp transitions.

2. The Evasé duct sections to the upper and lower windboxes have included angles greater than 30°. Disturbances in flow and distribution problems can be expected from these transmissions as well.

3. Register air doors and register air vanes begin to throttle airflow when they are closed to less than a 60% open position. With the linkage set-up on B&W burners, it is impossible to assure that all burners are identically set with respect to air door and air vane positions. Therefore, due to the high closure positions of the burners on the units at IPGS, it can be expected that the burners will have significant flow differences just due to the throttling effects.

### 5.2.2 Solutions

It is recommended that the airflow on the units be balanced and then a determination be made as to need for balancing fuel. Three alternatives for airflow balancing are available to IPSC. They are:

1. Insitu Airflow Balancing - This technique is the most accurate of the three techniques. Since actual airflow data is taken on your unit and corrective measures are made on your unit, the airflow balancing results are absolute. However, this technique requires that a two inch ID pipe be inserted down the center line of each coal pipe to permit insertion of special velocity probes. Balancing will require five to ten days of unit down-time with fan availability for testing. A construction crew must also

be on standby for installation of register bands, vortex breaking plates, and/or turning vanes as determined by test results.

2. Fluid Dynamics Modeling - Although not quite as accurate as insitu airflow balancing, a three-dimensional fluid dynamics model, when based upon accurate "as-built" drawings and field measured, airflow velocity data, is a very good way to model and correct airflow problems on units which do not permit insitu airflow balancing. The potential drawbacks are inaccuracies in the "as-built" drawings and field test data. Also, corrective measures recommended by the model may not be installed in the field correctly. Three-dimensional fluids models have the added benefit of allowing simulation of the combustion process to determine if the presence of a combustion process creates a furnace pressure gradient which will affect airflows to the burners.

3. Physical Modeling - Physical scale models are another very good way of modeling and correcting airflow balance on units which do not permit insitu balancing. The pros and cons for physical models are the same as for three-dimensional fluids model with the additional potential errors which may occur due to scaling and the fact that furnace pressure gradients due to combustion are not measurable in physical models.

It is recommended that IPSC select one methodology listed above for balancing airflows to the units. Depending upon IPSC's selection, RJM Corporation will perform the following activities:

#### 5.2.2.1 Insitu Airflow Balancing

RJM Corporation will employ a two-phase procedure for the Burner-Windbox Air Distribution Balancing as follows:

1. Field Testing - The testing of this unit will be done with the boiler off-line. Field testing will consist of the following steps:

   NOTE: Complete windbox and burner drawings are needed prior to testing to determine test probe dimensions and to set up the cartesian coordinates for test points and burner center lines. A two inch ID pipe down the center line of your burners is required for this balancing procedure to allow access to the burner throat airflows by RJM's test equipment.

   a) The air register configuration need to be identical for each burner and required to be open to a minimum of 80%.

   b) The flame stabilizers or air vanes must be set identically for each burner.

   c) The FD fans will be operated to the level associated with the operation of the unit at normal load.

   d) RJM Corporation will record the individual analysis of each burner using our proprietary electronic velocity probe analysis. Your company is to provide 120 volt/1 ph/60 hz power (15 amps) adjacent to burner decks and one technician/mechanic to assist in probe placement.

   e) Baseline test data will be gathered and decisions made for installing throttling bands on outer zone air doors, adjustment of inner zone air baffle and installation of vortex breaking baffles on turning vanes to correct windbox airflow problems. The unit will then be retested and additional adjustments made on an iterative basis until the $\pm 3\%$ airflow balance objective has been achieved.

2. Test Report - The test report will be issued, containing the following information:

   a) Results of the balanced airflow test results.

   b) Test Data Summary - The test data summary is the most important analytical tool generated by the Burner-Windbox Analysis Technique. This summary shows data collected at 24 data points around the perimeter of the burner, including:

      1) High, low and average velocities at each test point.

      2) The average velocity for all burners.

      3) The peak velocity for each burner.

      4) The percent deviation of airflow from the average airflow for all burners.

      5) Flagging of vortex eddy action in the windbox by segment.

      6) Flagging of segments experiencing obstructed flow.

      7) Flagging of segments where blocked airflow and vortex eddies are both contributing to airflow deviations.

c) Composite Burner Projections - Field data is translated into a composite burner projection which, in RJM Corporation's computer system, can be viewed from any direction. The composite projection is particularly useful in visually relating the performance of one burner in relation to all other burners.

d) Windbox Distribution Pattern - This pattern is produced by regressing the burner velocity profiles to show the pressure head (distribution) profile which created the velocities in the burners. This pattern is particularly useful in helping to determine where in the windbox, or ducting, the windbox distribution problems may be originating.

e) Individual Burner Projections - Data on individual burners is presented in three-dimensional formats which are helpful in defining the extent of perimeter loading problems.

### 5.2.2.2 Three-Dimensional Fluids Model

The program action plan will consist of the following:

1. Your company will provide to RJM Corporation all detailed certified "as-built" drawings of the selected unit necessary to construct an accurate model. Detail drawings are to include all ductwork, structural members, burners, furnace dimensions, etc., from the air heater outlet to the furnace nose.

2. Your company will also provide test data on the velocity profiles at the air heater outlet and the inlets to the shut-off dampers in

each windbox. Velocity profile data is also to include velocity vectors as determined by pito tube positioning.

3. RJM Corporation will then develop a CAD model from the air heater outlet to the furnace nose which accurately depicts the present configuration of your unit.

4. The model will then be subjected to finite volume or nodal analysis on a one, two and three-dimensional basis to determine airflow patterns existing in your present unit. Based on these tests, changes will be made to the model to improve the airflow distribution. The objective of the model testing will be to achieve airflow distribution to $\pm 3\%$. Splitters, turning vanes, and baffles or diffuser plates will be inserted into the model and continually tested until the airflow and bulk flow is equal. At the same time, windbox vortex eddies will be eliminated and linear flow obtained to each burner.

5. RJM Corporation will prepare general drawings showing the type and location of any corrective devices needed, based on the computer model results. These corrective devices may include:

   a. Turning vanes and ductwork elbows in windbox
   b. Windbox directional vanes
   c. Vortex splitters
   d. Impingement baffles

6. Windbox modification and final performance results will be presented in a detailed report for implementation by your contractors at your expense.

### 5.2.2.3 Physical Model

The program action plan will consist of the following:

1. Your company will provide to RJM Corporation all detail certified "as built" drawings of the selected unit necessary to construct an accurate model. Detail drawings are to include all ductwork, structural members, burners, furnace dimensions, etc., from the air heater outlet to the furnace nose.

2. RJM Corporation will provide all necessary engineering and materials to construct a scale model of the selected unit from the air heater outlet to the furnace nose.

3. The model will be scaled to accurately reproduce the flow characteristics of the actual unit. It is estimated that a 1:10 scale will be used. The proposed new burners will be simulated.

4. The models will be flow tested with smoke made up of several different available chemicals. Smoke is used for two reasons: (1) its density is virtually the same as air; and (2) when illuminated for photography, the light deflection is suitable for video taping and photography. Your company will be given a video tape showing before and after test results as a part of this program. Based on these tests, changes will be made to the model to improve the air distribution. The objective of the model testing will be to achieve airflow distribution to $\pm 3\%$. Splitters, turning vanes, and baffles and diffuser plates are installed in the model and continually tested until the airflow and bulk flow is equal. At the same time, the windbox vortex eddies are eliminated and linear flow is obtained through each burner. The Reynolds Number is

generally kept above $10^4$ to assure simultaneity between the model and the field unit.

5. RJM Corporation will prepare general drawings showing the type and location of any corrective devices needed, based on the actual model testing. These corrective devices include:

   a. Turning vanes in ductwork elbows and windbox
   b. Windbox directional vanes
   c. Vortex splitters
   d. Impingement baffles

6. Windbox modifications and final model performance results will be presented in a detailed report for implementation by your contractors at your expense.

#### 5.2.2.4 Coal Flow Balancing

RJM Corporation will employ a multi-phase procedure for Coal Flow Analysis and Balancing. A Coal Pipe Coal Distribution Analysis (CDA) will be performed to determine the total coal flow and the distribution the coal pipe. During this phase of the program, an RJM Corporation engineer will perform the following:

1. Collect data on current operating performance and review boiler operation.

2. Measure and record individual mill settings and specifications.

3. Establish that test prerequisites can be met. Test prerequisites are:

a. That complete burner drawings and coal pipe arrangement are available to set up the cartesian coordinates for test points and burner center lines.

b. That each burner has a center line access port through which our test probe can be inserted.

4. Review test procedures with operating personnel.

a. Review and implement the correct operation of the coal feeders for the proper testing position. Plant personnel will review with the field engineer how to operate the mills for testing and agree to the operation mode for proper boiler operation.

b. Establish the number of burners to be out of service and the specifications for primary air and mill operation. RJM expects to perform this test with one coal feeder out of service.

5. Develop a test schedule with plant personnel.

6. Field testing will consist of the following steps:

a. Mills will be operated as agreed.

b. RJM Corporation will take the individual analysis of each coal pipe using our proprietary velocity probe analysis. Each coal pipe will be analyzed under two conditions, these conditions are:

1) RJM Corporation will take readings int he coal pipe in 8 locations twice. The first test will be done with the agreed coal feeder off. This test referred to as the clean air test will establish the base distribution of the primary air.

2) The second test will be done with the coal feeder "on" and the coal pipes supplying normal coal. This test will be referred to as the dirty air test.

c. The data gathered as a result of this test will be reviewed and corrective action will be presented to your company for implementation.

d. Testing and continuous refinements will be made until coal flow balance has been achieved within $\pm 5\%$.

7. A Coal Distribution Analysis report will be issued and will contain the following information:

a. CDA Test Data Summary - The test data summary is the most important analytical tool generated by the CDA technique. This summary shows data collected around the perimeter of the burner including:

1) High, low and average velocities at each test point.

2) The average mass coal for all burners.

3) The peak coal flow for each burner.

4) The percent deviation of coal-flow from the average coal-flow for all burners.

5) Flagging or segments experiencing obstructed flow.

b. Composite Coal Flow Projections - Field data is translated into a composite projection which, in RJM Corporation's computer system, can be viewed from any direction. The composite projection is particularly useful in visually relating the performance of one burner in relation to all other burners.

c. Individual Coal Pipe Projections - Data on individual coal-pipes is presented in three-dimensional formats ("cones") which are helpful in defining the extent of the perimeter loading problems that affect the temperature imbalances. The report will include one "cone" for each coal-pipe. This "cone" will be the difference of the data taken from the clean air test and the dirty air test which will leave a "cone" depicting the mass coal flow and the distribution.

## 6.0 BUDGET

RJM Corporation will perform the Action Plan as defined in this report for the fees defined below. Except as noted, all fees are quoted on a fixed price basis and are inclusive of all travel and per diem costs. State excise or sales taxes are not included and, if applicable, will be an additional charge to your account. Field delays beyond RJM Corporation's control, resulting in additional expenses to RJM Corporation, will be charged to your account in accordance with our Fees, Terms and Conditions schedule which is attached.

1. Burner Airflow Model . . . . . . . . . . . . . . . . . . . . . . . . 9,000.00

2. MZ Flame Stabilizers
   a. Engineering and Design (one time charge) . . . . . . . . 7,200.00
   b. 48 Stabilizers ($1800.00/stabilizer) . . . . . . . . . . . 86,400.00

3. Burner Mechanical Design Optimization . . . . . . . . . . . . 27,000.00

4. Air Distribution Analysis . . . . . . . . . . . . . . . . . . . . . . 34,300.00
   Air Distribution Balancing . . . . . . . . . . . . . . . . . . . . . 40,000.00

5. Fuel Flow Analysis . . . . . . . . . . . . . . . . . . . . . . . . . 28,600.00
   Fuel Flow Balancing . . . . . . . . . . . . . . . . . . . . . . . . 24,400.00

6. Airflow Models
   a. Three-dimensional fluids model . . . . . . . . . . . . . 76,000.00
   or
   b. Physical Model . . . . . . . . . . . . . . . . . . . . . . . . 93,000.00

## 7.0 SCHEDULE

The sequence of events for this project should be in the following priority order:

1. Optimize burner mechanical design

2. Optimize burner aerodynamics

3. Design MZ flame stabilizer

4. Upon completion and acceptance of all aerodynamics and mechanical design, manufacture 48 MZ flame stabilizers.

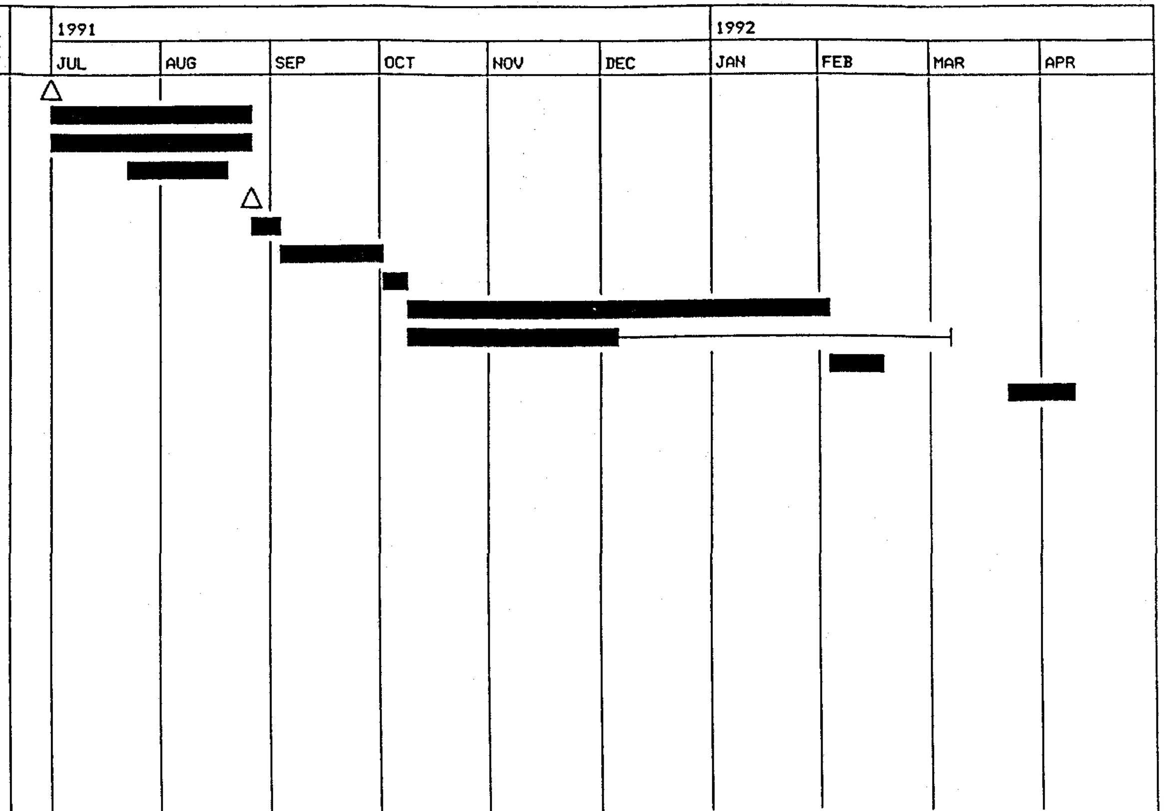
5. Select airflow balancing technique.

   If insitu airflow balancing is the selected technique, balancing should not take place until after the new burners have been installed. If three-dimensional fluids modeling or physical modelling is the desired technique, balancing on the models can begin before or after new burner installation.

6. After new burners are installed undertake fuel flow balancing.

Figure 5 presents RJM's estimated critical path schedule for this project. Air and fuel flow balancing are not shown on the critical path schedule since IPSC has great flexibility with scheduling these programs.

| TASK NAME | DUR | EARLY START | TOTAL SLACK |
|---|---|---|---|
| BEGIN BURNER DESIGN WORK | 0 | 01JUL91 | 0 |
| BURNER 2D AIRFLOW MODEL | 40 | 01JUL91 | 0 |
| OPTIMIZE BURNER MECH DESIGN | 40 | 01JUL91 | 23 |
| MZ FLAME STABILIZER DESIGN | 20 | 23JUL91 | 0 |
| COMPLETE ALL DESIGN WORK | 0 | 27AUG91 | 0 |
| IPSC DESIGN APPROVAL | 5 | 27AUG91 | 23 |
| B&W FINAL DESIGN DRAWINGS | 20 | 04SEP91 | 23 |
| IPSC FINAL DRAWING APPROVAL | 5 | 02OCT91 | 23 |
| B&W BURNER FABRICATION | 80 | 09OCT91 | 23 |
| MANUFACTURE FLAME STABILIZERS | 40 | 09OCT91 | 63 |
| BURNER DELIVERY TO IPSC | 10 | 04FEB92 | 0 |
| BURNER INSTALLATION | 15 | 23MAR92 | 0 |




LEGEND

TASK NAME — SLACK

MILESTONE

Enhanced

Figure 5

RJM CORPORATION

INTERMOUNTAIN POWER SERVICE CORPORATION

NEW BURNER OPTIMIZATION PROGRAM

RUN DATE 17JUN91
AS OF DATE 14JUN91

TIME LINE R GRAPHICS